THE BIOENERGETIC REQUIREMENTS FOR GROWTH AND MAINTENANCE OF RAPTORS COMMON TO THE SNAKE RIVER BIRDS OF PREY NATURAL AREA

by

Michael W. Collopy
2011 Cleveland St.
Boise, ID 83705

for

Idaho State Office
Bureau of Land Management
P.O. Box 042, Federal Bldg.
Boise, ID 83724
(Contract # ID-910-CT8-0003)

In this study I have attempted to quantify the energetic requirements of two Golden eagle (Aquila chrysaetos) chicks, one Prairie falcon (Falco mexicanus) chick, one Red-tailed hawk (Buteo jamaicensis) chick, and one subadult Prairie falcon. The methodology used to obtain measurements of metabolized energy, and its allocation to maintenance and growth, was based on the work of Kendeigh (1949) and subsequent investigators (Davis 1955; West 1960; Koplin et al 1976).

Food consumption studies are based on the relationship $A = I - E = M + P$, where A is assimilated energy, I is the energy consumed (food), E is the energy egested (pellets and excrement), M is the energy released through oxidative metabolism, and P is the energy contained in new tissue and the energetic cost of that production (Petrusewicz and Macfadyen 1970; Gessaman 1973). The energy ingested and egested was calculated from each feeding trial, based on the biomass of consumed food, the biomass of rejected pellets and excrement, and their respective caloric equivalences. From these values I calculated the total amount of energy assimilated. When no growth was observed (e.g. with the subadult Prairie falcon), the energy assimilated daily was considered the existence metabolism (Gessaman 1973). However, with growing chicks, the assimilated energy is allocated to both existence metabolism and production. Existence metabolism, which includes the cost of basal metabolic rate, thermoregulation, specific dynamic action, and locomotory activities, was calculated for each bird from equations developed by Kendeigh (1970). The difference between assimilated energy and the calculated existence metabolism was considered the amount of energy available for growth.

The assimilation efficiency (AE) is the proportion of energy consumed which is both digested and metabolized, and can be expressed as $AE = A/I$,

where A is assimilated energy and I is the energy consumed. The assimilation efficiency of each study bird was calculated after each feeding trial experiment.

Methods

Acquisition and Deposition of Study Birds

Personnel from the Snake River Birds of Prey Research Project (SRBPRP) selected the birds to be used in this study. Both Golden eagle chicks were delivered to me on 21 March 1978. The Red-tailed hawk chick was delivered on 13 May 1978, and the Prairie falcon chick was delivered on 6 June 1978. The subadult Prairie falcon was in my possession since July 1977, when he was rescued from an abandoned scrape in the Birds of Prey Natural Area (BPNA). Federal Scientific Collecting Permit #PRT-20692-PT and State Scientific Collecting Permit 12/74, both granted to Mr. Michael N. Kochert, authorized my possession of all study birds.

When I first received the eaglets, who were siblings, the younger of the two had a severe wound on its back which had developed from constant pecking by its older sibling. She also appeared stunted and malnourished. Neosporin ointment was applied daily to the wound and it healed without infection.

During the early stages of the feeding trials, what appeared to be vitamin deficiencies developed in the younger eaglet and the Red-tailed hawk chick. This resulted in each chick losing the muscular coordination in its legs. X-rays were taken which showed no structural deformities. The legs were then taped together to prevent them from splaying apart. Multiple vitamins and calcium pills were administered daily, and within a week both chicks had regained muscular control. Shortly thereafter both chicks were standing and walking with no difficulty.

At approximately one week prior to fledging, each chick was fostered into a nest on the BPNA. All chicks successfully fledged, and were each seen near their foster nest up to three weeks after fledging (Kochert pers. comm.).

The subadult Prairie falcon is currently in my possession. He will soon be given, by the BLM, to a competent falconer who will then train him to hunt and hack him back into the wild.

Housing Facilities

Each study bird was housed in an individual cubicle constructed to facilitate the collection of excrement. A mews (1.83m x 3.96m) was provided by the BLM, in which I housed both eaglets. I enlarged the size of their cubicles as the body size and space requirements of the birds increased. I was especially careful to provide sufficient space so that normal exercising behaviors (e.g. flapping wings) could occur without feather damage. Initially, the cubicles were 0.67m (2.2 feet) x 0.91m (3.0 feet). Later, they were enlarged to 0.98m (3.2 feet) x 1.92m (6.3 feet).

All other study birds were housed in a spare room (2.59m x 4.05m) at my residence. The Prairie falcon and Red-tailed hawk chicks were each housed in cubicles 0.91m (3.0 feet) x 1.28m (4.2 feet). The subadult Prairie falcon was tethered to a perch on a table, and was permitted to move in an area 1.01m (3.3 feet) x 1.19m (3.9 feet).

Acquisition and Preparation of Food

I attempted to feed each study bird as natural a diet as possible. The prey fed to each bird during the feeding trials was that species which comprised the greatest proportion (by biomass) of its diet in the wild (Kochert et al 1976). The Golden eagles were fed black-tailed jackrabbits (*Lepus californicus*), and the Prairie falcons and Red-tailed hawk were fed Townsend ground squirrels (*Spermophilus townsendi*).

At approximately one week prior to fledging, each chick was fostered into a nest at the site. All chicks successfully fledged, and were seen near their foster nest up to three weeks after fledging (Gerhardt pers. comm.).

The mealworm feeding table is currently in my possession. [illegible] to others, [illegible] the NRP, [illegible] able to [illegible] the [illegible].

Housing Facilities

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I was [illegible] to [illegible] each [illegible] behavior (e.g., [illegible]) [illegible] damage. Initially, the [illegible]. Later, [illegible] 1.5m (5.0 feet).

All other study birds were housed in [illegible]. The [illegible] (1.2 feet) x 1.5m (5.0 feet). The [illegible] was [illegible] in a [illegible], and was [illegible] of [illegible] 0.9m (3.0 feet) x 1.2m (4.0 feet).

Acquisition and Preparation of Food

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It has been documented that the energy content of small mammals can exhibit great seasonal variation (Gorecki 1965; Schreiber and Johnson 1975). For this reason, samples of jackrabbits and ground squirrels were collected periodically during the feeding trial experiments (Table 1). My objective was to provide each study bird with the type of food it normally would have received in the wild. I wish to thank Larry Oftedahl and Graham Smith for so willingly collecting the necessary jackrabbits and ground squirrels.

Each collection of prey was eviscerated and then homogenized with a meat chopper. All individuals within a given collection were mixed together to insure a food source of relatively constant caloric value. The food was then bagged, labeled and frozen for future use.

Feeding Trials

A total of seven feeding trials were conducted with each Golden eagle chick, four with both the Prairie falcon and Red-tailed hawk chicks, and eight with the subadult Prairie falcon.

At the beginning of each feeding trial, the study bird's cubicle was lined with clean plastic sheeting. The untethered individual was then placed inside the cubicle (the subadult Prairie falcon was tethered to a perch centered on the plastic). Every morning before the first meal the birds were weighed, and any regurgitated pellets were collected. Throughout all feeding trials each study bird was fed approximately the same number of times per day as wild birds were being fed (Kochert pers. comm.) (Appendix I, II, and III). At each meal the birds were allowed to eat until they were full. The amount of food presented and the amount left over was weighed. The difference between these values equaled the actual amount of food consumed per meal (Appendix I, II, and III).

The technique used to feed the subadult Prairie falcon differed in that he was fed twice a day, and only that amount which maintained a constant

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Feeding trials

A total of [illegible] feeding trials were conducted with each [illegible], four with both the [illegible] and [illegible], and eight with the [illegible].

At the beginning of each feeding trial, the study bird's [illegible] was lined with clear plastic sheeting. The [illegible] individual was then placed [illegible] the [illegible] outside [illegible] was [illegible] on a [illegible] of the plastic. Every [illegible] below the [illegible] the [illegible] were [illegible], and any regurgitated pellets were collected. Throughout all feeding trials each study bird was fed approximately the same number of times per day as wild birds were being fed [illegible] (Appendix I, II, and III). At each meal the birds were allowed to eat until they were full. The amount of food presented and the amount left over was weighed. The difference between these values equaled the actual amount of food consumed per meal (Appendix I, II, and III).

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body weight (Appendix IV).

Each feeding trial was terminated after four to eight days, depending on the species. At this time the plastic which collected the excrement was removed and allowed to dry. After the excrement was thoroughly dried, it was scraped from the plastic and stored in glass containers. The dried pellets regurgitated during the trial also were stored in glass containers.

Feeding trial experiments on each of the chicks were conducted consecutively. When one feeding trial ended and the plastic was removed, it was replaced and the next trial started. Feeding trials on the subadult Prairie falcon were conducted less frequently and over a longer period of time. Temperature was monitored during each trial with thermographs.

Laboratory Analyses

All pellets and excrement collected from each feeding trial, and a sample of the food consumed during that trial were taken to Hibbs Laboratories, Boise, Idaho. Weights on the total biomass of pellets and excrement obtained from each feeding trial were determined after oven drying (@ 65 degrees F.). Anhydrous ether fat extractions (Soxhlett method) were then performed on samples of food, pellets and excrement. These analyses provided percent water and percent fat values for all collections of jackrabbits and ground squirrels (Table 1), and percent fat values for the pellet and excrement samples from each feeding trial (Appendix V).

Samples of the fat extracted from the food, and all fat-free extracts of the food, pellets and excrement associated with each feeding trial was sent to Dr. James R. Koplin, Humboldt State University, where the bomb calorimetry analyses were performed. These analyses provided data on energy content (kcal/gm , dry weight) for the fat and fat-free extracts of each prey species (Table 1), and the fat-free extracts of the pellets and excrement from each feeding trial conducted on each study bird (Appendix V).

body weight (Appendix IV).

Each feeding trial was terminated after four to eight days, depending on the species. At this time the plastic sheets holding the excrement were removed and allowed to dry. After the excrement was thoroughly dried, it was scraped from the plastic and placed in a gas container. The dried pellets regurgitated during the trial also were stored in glass containers.

Feeding trial experiments on each of the species were conducted separately. When one feeding trial ended and the [illegible] removed, it was reweighed and the next trial started. Feeding trials on the [illegible] [illegible] were conducted less frequently and over a longer period of time. Temperature was monitored during each trial with thermographs.

Laboratory Analyses

All pellets and excrement collected from each feeding trial, and a sample of the food consumed during each trial, were taken to [illegible] Laboratories, [illegible]. Weights of the total amount of pellets and excrement obtained from each feeding trial were determined after oven drying ([illegible] degrees F.). Analyses other than extractions ([illegible]) were then performed on samples of food, pellets and excrement. These analyses provided percent water and percent fat values for all collections of jackrabbits and ground squirrels (Table 1), and percent fat values for the pellet and excrement samples from each feeding trial (Appendix V).

Samples of the fat extracted from the food, and all fat-free remnants of the food, pellets and excrement associated with each feeding trial was sent to Dr. [illegible], [illegible] State University, where the bomb calorimetry analyses were performed. These analyses provided data on energy content (kcal/gm., dry weight) for the fat and fat-free extracts of each prey species (Table 1), and the fat-free extracts of the pellets and excrement from each feeding trial conducted on each study bird (Appendix V).

Results and Discussion

Energy Content of Prey

Black-tailed jackrabbits are active year-round. The percent water content found in their tissues increased gradually from mid-April to mid-May (Table 1). Although the time span over which the three samples were collected was brief, the data are in agreement with the gradual spring and summer increases in percent body water found in other rodents which are active year-round (Schreiber and Johnson 1975). This increase may reflect a recovery from dehydration which occurs during the cold winter months (Schreiber and Johnson 1975). The percent fat content in the body showed no clear trend (Table 1). Differences observed between the three collections may only reflect individual variation within the samples.

Townsend ground squirrels are seasonally active small mammals. They normally emerge in January and February, as the weather warms up, and enter torpor from mid-May to mid-July, depending on sex and age (Johnson et al 1976). Six collections of ground squirrels were made throughout the period of above-ground activity (Table 1). Values for water and fat content varied inversely, with the percent fat content ranging from 15 percent in February to a peak of 43 percent prior to submergence in May. This ability to rapidly accumulate body fat is found in other seasonally active rodents, but not to this extent (Schreiber and Johnson 1975).

The caloric values for fat and fat-free extracts of jackrabbit and ground squirrel carcasses are very similar (Table 1). The mean energy content of jackrabbit fat, based on three samples, is 9.265 kcal/g (dry weight). The caloric content of ground squirrel fat is 9.250 kcal/g (dry weight) (range: 9.183 - 9.318 kcal/g). Fat-free energy values for black-tailed jackrabbits averaged 4.365 kcal/g (dry weight), ranging from 4.230 to 4.503

kcal/g. The caloric equivalent of fat-free ground squirrel averaged 4.218 kcal/g (dry weight), ranging from 4.103 to 4.509 kcal/g. It appears that the energy content of rodent fat and fat-free extracts are both fairly uniform throughout the season, and that differences in the energy value of individual prey items can be related primarily to body composition.

Food Consumption and Assimilation Efficiency

Data on the daily food consumption of all study birds are presented in Appendices I, II, III, and IV. During the first feeding trial, both Golden eagle chicks consumed daily an average of 35 and 48 percent of their body weight. By the seventh feeding trial, they were consuming an average of 14 and 17 percent of their respective body weights daily (Appendix I). These final values are greater than twice the consumption rates of adult and juvenile eagles studied by Fevold and Craighead (1958). By the seventh trial, each of the study eaglets was less than 85 percent of adult weight (each were determined to be females). This certainly accounts for the much greater rate of food consumption, and reflects the energetic demands of producing body tissue and feathers.

During the feeding trials, decreases in the percent of body weight of food consumed daily were observed in both the Prairie falcon and Red-tailed hawk chicks (Appendix II and III). The falcon consumed an average of 15 percent of its body weight during the first feeding trial, and 9 percent during the fourth and final trial (Appendix II). The Red-tailed hawk decreased its percent body weight consumption from 32 to 13 percent, from the first to the fourth trial, respectively (Appendix III).

The mean daily consumption of the subadult Prairie falcon was fairly constant within similar temperature regimes (Appendix IV). This reflects the increased energy requirements for thermoregulation during periods of

kcal/g. The caloric equivalent of fat-free ground squirrel averaged 6.218 kcal/g (dry weight), ranging from 6.103 to 6.300 kcal/g. It appears that the energy content of rodent fat and fat-free substance are both fairly uniform throughout the season, and that differences in the energy value of individual prey items can be related primarily to body composition.

<u>Food Consumption and Assimilation Efficiency</u>

Data on the daily food consumption of all study birds are presented in Appendices I, II, III, and IV. During the first feeding trial, both Golden eagle chicks consumed daily an average of 29 and 28 percent of their body weight. By the seventh feeding trial, they were consuming an average of 14 and 17 percent of their respective body weights daily (Appendix I). These final values are greater than twice the consumption rates of adult and juvenile eagles studied by Fevold and Craighead (1958). By the seventh trial, each of the eagle chicks was less than 85 percent of adult weight (weights designated by Brown and Amadon 1968). This certainly accounts for the much greater rate of food consumption, and reflects the energetic demands of producing body tissue and feathers.

During the feeding trials, decreases in the percent of body weight of food consumed daily were observed in both the Prairie Falcon and Red-tailed Hawk chicks (Appendix II and III). The Falcon consumed an average of 19 percent of its body weight during the first feeding trial, and 9 percent during the fourth and final trial (Appendix II). The Red-tailed Hawk decreased its percent body weight consumption from 19 to 13 percent, then to 11 in the fourth trials, respectively (Appendix III).

The mean daily consumption of the breeding Prairie Falcons was fairly constant within similar temperature regimes (Appendix IV). This reflects the increased energy requirements for thermoregulation during periods of

temperature stress. During feeding trials #2, 3 and 4, the mean ambient temperature was 12.1 degrees C., and the amount of food consumed daily averaged 12.7 percent of body weight. Later in the spring, during feeding trials #6, 7 and 8, the mean ambient temperature was 17.8 degrees C., and the daily food consumption averaged 8.0 percent of body weight.

Assimilation efficiency has been defined as the ratio of assimilated energy to consumed energy, and is known to be influenced by age, temperature and characteristics of the food (Kleiber 1961, Petrusewicz and Macfadyen 1970). The assimilation efficiencies of each study bird during it feeding trials is presented in Table 2. The two Golden eagle chicks had efficiencies averaging 74.8 and 73.9 percent. The Prairie falcon and Red-tailed hawk chicks had efficiencies averaging 83.5 and 84.7 percent, respectively. The greater values exhibited by the Prairie falcon and Red-tailed hawk reflect the greater percent of fat in their diets. The diets of both the Prairie falcon and Red-tailed hawk chicks contained over 30 percent fat, of which they were able to metabolize over 99 percent. The eagle chicks not only consumed fat in a much smaller proportion (3.3 percent), but were slightly less efficient at assimilating it (Table 2).

Overall, the subadult Prairie falcon was 81.5 percent (76.8 - 87.8 percent) efficient at assimilating the food energy consumed (Table 2). This value is lower than that reported for the Prairie falcon chick, however, when the assimilation efficiencies of both falcons are calculated based on diets of equal fat content (PF subadult trials #7 and 8, PF chick trials #3 and 4), the subadult is 87.2 percent efficient and the chick is only 81.8 percent efficient.

The feeding trials of the subadult Prairie falcon were spaced over four of the five ground squirrel collections, which ranged in fat content

from 15.1 to 39.1 percent. A regression analysis was performed to assess the relationship between assimilation efficiency and percent fat content in the food (Figure 1). The results indicate a highly significant linear correlation between assimilation efficiency and percent fat in the diet ($t_{7df} = 5.225$, $p < 0.01$; $r = 0.892$). This same relationship probably exists with the growing chicks, however, the food presented to them during the feeding trials did not have sufficient variability in fat content for any significant correlation to be detected.

The observed assimilation efficiencies are in accordance with those reported in the literature for other raptor species. Graber (1962) and Duke (1973) calculated that captive Long-eared owls (_Asio otus_) and Great horned owls (_Bubo virginianus_) were 87 and 85 percent efficient at assimilating vertebrate prey. Gessaman (1972) found that Snowy owls (_Nyctea scandiaca_) had assimilation efficiencies of 70 percent indoors and 74 to 80 percent outdoors. Koplin et al (1976) reported that captive falconiforms of seven species (including an adult Prairie falcon and Red-tailed hawk) assimilated an average of 83 percent of the vertebrate prey they consumed.

An important consideration when comparing assimilation efficiencies is to know the percent fat content in the food used. As illustrated with the subadult Prairie falcon, the efficiency of assimilation can vary greatly as the relative body composition of the prey changes.

Metabolized Energy

The average amount of energy metabolized (ME) daily, during each feeding trial, was calculated from the expression $ME = I - E$, where I is the food energy ingested daily, and E is the energy (pellets and excrement) egested daily. In this report, ME is expressed as a daily rate per individual bird. I is expressed as $kcal \cdot bird^{-1} \cdot day^{-1}$, and is calculated using the following

from 19.1 to 39.1 percent. A regression analysis was performed to assess the relationship between assimilation efficiency and percent fat content in the food (Figure 13). The results indicate a highly significant linear correlation between assimilation efficiency and percent fat in the diet ($F_{1,90}$ = 53.225, p<0.001, r = 0.6055). This same relationship probably exists with the grass shrimp, however, the data presented on them during the feeding trials did not have sufficient variability in fat content for any significant correlation to be detected.

The observed assimilation efficiencies are in accordance with those reported in the literature for other raptor species. Graber (1962) and Duke (1977) calculated that captive Long-eared owls (Asio otus) and Great-horned owls (Bubo virginianus) were 80 and 77 percent efficient at assimilating vertebrate prey. Gessaman (1972) found that Snowy owls (Nyctea scandiaca) had assimilation efficiencies of 76 percent in winter and 78 to 80 percent in summer. Duke et al (1975) reported that captive falconiforms of seven species (including an adult Prairie falcon and Red-tailed hawk) assimilated an average of 83 percent of the vertebrate prey they consumed.

An important consideration, when comparing assimilation efficiencies is to know the percent fat content in the food used. As illustrated with the captive Prairie falcon, the efficiency of assimilation can vary greatly, as the relative body composition of the prey changes.

Metabolized Energy

The average amount of energy metabolized (ME) daily, during each feeding trial, was calculated from the expression ME = I - E , where I is the food energy ingested daily, and E is the energy (pellets and excreta) egested daily. In this report, ME is expressed as a daily rate per individual bird. I is expressed as kcal·bird^{-1}·day^{-1} , and is calculated using the following

equation:

$$I = \frac{(1-\%W)(B)((\%F_b)(C_f) + (\%L_b)(C_l))}{H/24},$$

where: $\%W$ = percent water in prey used
B = biomass (gm) of fresh prey consumed per trial
$\%F_b$ = percent fat in prey used (on a dry weight basis)
C_f = caloric value for fat (kcal/g, dry weight)
$\%L_b$ = percent fat-free material in prey used (on a dry weight basis)
C_l = caloric value for fat-free material (kcal/g, dry wdght)
H = length of feeding trial in hours
(See Appendix VI).

E also is expressed in $kcal \cdot bird^{-1} . day^{-1}$, and is calculated by the equation:

$$E = \frac{P((\%F_p)(C_f) + (\%L_p)(C_{lp})) + R((\%F_r)(C_f) + (\%L_r)(C_{lr}))}{H/24},$$

where: P = biomass of pellets egested per trial (gm, dry weight)
$\%F_p$ = percent fat in pellets (dry weight)
C_f = caloric value of fat (kcal/g, dry weight)
$\%L_p$ = percent fat-free material in pellets (dry weight)
C_{lp} = caloric value of fat-free material in pellets (kcal/g, dry wwight)
R = biomass of excrement voided during feeding trial (gm, dry weight)
$\%F_r$ = percent fat in excrement (dry weight)
$\%L_r$ = percent fat-free material in excrement (dry weight)
C_{lr} = caloric value of fat-free material in excrement (kcal/g, dry wt.)
H = length of feeding trial in hours
(See Appendix VI).

The mean values obtained for daily metabolized energy (ME) per feeding trial are presented for each study bird in Table 3.

Maintenance and Growth Requirements

In growing chicks, metabolized energy is allocated primarily to maintenance and growth processes. The amount of ME actually allocated to maintenance was predicted by equations developed by Kendeigh (1970):

All species; 0 C.: $EM = 4.3372\,W^{0.5300}$
Non-Passerines; 30 C.: $EM = 0.5404\,W^{0.7545}$

These temperature-specific, weight-independent equations were modified to be

equation:

$$I = \frac{(B - MW)(W)[(\%F_g)(C_f) + (\%N_g)(C_n)]}{T/24}$$

where: MW = percent water in grey seed
B = Amount (gm) of fresh feed provided per trial
$\%F_g$ = percent fat in grey seed (on a dry weight basis)
C_f = caloric value for fat (kcal/g, dry weight)
$\%N_g$ = percent fat-free material in grey seed (on a dry weight basis)
C_n = caloric value for fat-free material (kcal/g, dry wt)
T = length of feeding trial in hours
(See Appendix VI).

E also is expressed in kcal·bird^{-1}·day^{-1}, and is calculated by the equation:

$$E = \frac{P[(\%F_p)(C_f) + (\%N_p)(C_{np})] + M[(\%F_m)(C_f) + (\%N_m)(C_{nm})]}{T/24}$$

where: P = amount of pellets egested per trial (gm dry weight)
$\%F_p$ = percent fat in pellets (dry weight)
C_f = caloric value of fat (kcal/g, dry weight)
$\%N_p$ = percent fat-free material in pellets (dry weight)
C_{np} = caloric value of fat-free material in pellets (kcal/g, dry weight)
M = amount of excrement collected during feeding trial (gm, dry weight)
$\%F_m$ = percent fat in excrement (dry weight)
$\%N_m$ = percent fat-free material in excrement (dry weight)
C_{nm} = caloric value of fat-free material in excrement (kcal/g, dry wt.)
T = length of feeding trial in hours
(See Appendix VI).

The mean values obtained for daily metabolized energy (ME) per feeding trial are presented for each study bird in Table 2.

Maintenance and Growth Requirements

In growing animals, metabolized energy is allocated primarily to maintenance and growth processes. The amount of ME actually allocated to maintenance was predicted by equations developed by Kendeigh (1970):

All Species: M.C. = 4.337W$^{0.5300}$

Non-Passerines: M.C. = 5.1444W$^{0.5285}$

These temperature-specific, weight-independent equations were modified to be

weight-specific, and temperature-independent. Calculations of existence metabolism for each feeding trial were based on initial body weight and mean ambient temperature (Appendix VI). Mean ambient temperatures were calculated from hourly temperature data collected with thermographs. The difference between ME and the predicted existence metabolism (maintenance) was considered the amount of energy available for growth. Calculations of existence metabolism and growth energy per feeding trial are presented for each study bird in Table 3.

Energy Budgets of Captive Birds

The patterns of energy expenditure exhibited by each study bird conform to hypothetical models developed for altricial birds (Ricklefs 1974). The growth requirement of the energy budget is greater than maintenance until the chick reaches approximately 60 percent of its adult weight. Thereafter, it decreases steadily, and eventually falls below the increasing demands of maintenance metabolism.

The allocation of metabolized energy to maintenance and growth is illustrated for each Golden eagle chick in Figures 2 and 3. The growth component of the older chick's energy budget increased to a peak at approximately 40 percent of adult weight (three weeks old), and then decreased gradually until it fell below the maintenance requirements at approximately 70 percent of adult weight (five weeks old) (Figure 2).

The younger eaglet was under stress from wounds and malnutrition when she was small. This stress may have influenced the metabolic rate which was suppressed during her growth from 20 to 40 percent of adult weight (three to four weeks old) (Figure 3). I combined data from both eaglets to generalize the pattern of energy expenditure that might be expected from a typical eaglet (Figure 4).

weight-specific, and temperature-corrected. Calculations of existence metabolism for each feeding trial were based on initial body weight and mean ambient temperature (Appendix VI). Mean ambient temperatures were calculated from hourly temperature data collected with thermographs. The difference between ME and the predicted existence metabolism (maintenance) was considered the amount of energy available for growth. Calculations of existence metabolism and growth energy per feeding trial are presented for each study bird in Table 3.

<u>Energy Budgets of Nestling Birds</u>

The patterns of energy expenditure exhibited by each study bird conform to hypothetical models developed for altricial birds (Ricklefs 1974). The growth requirement of the energy budget is greater than maintenance until the chick reaches approximately 60 percent of the adult weight. Thereafter, it decreases steadily, and eventually falls below the increasing demands of maintenance metabolism.

The allocation of metabolized energy to maintenance and growth is illustrated for each Golden eagle chick in Figures 2 and 3. The growth component of the older chick's energy budget increased to a peak at approximately 40 percent of adult weight (three weeks old), and then decreased gradually until it fell below the maintenance requirements at approximately 70 percent of adult weight (five weeks old) (Figure 2).

The younger eaglet was under stress from mange and malnutrition when she was small. This stress may have influenced the metabolic rate which was suppressed during her growth from 20 to 40 percent of adult weight (three to four weeks old) (Figure 3). I combined data from both eaglets to generalize the pattern of energy expenditure that might be expected from a typical eaglet (Figure 4).

The Prairie falcon chick was not obtained until she had attained 80 percent of adult weight. Consequently, the data are incomplete. The allocation of energy to growth steadily decreased throughout the period studied, falling below the maintenance requirements at approximately 90 percent of adult weight (Figure 5). Since data are not available on younger Prairie falcon chicks, it is conceivable that the amount of energy required for growth actually fell below maintenance requirements earlier in the growing period. The energy metabolized in excess of that required for maintenance, allocated to growth in this model, also may have included the energetic cost of increased activity. This would bias the predicted growth requirements late in the growth period.

The Red-tailed hawk chick was obtained after she had attained 40 percent of adult weight. Throughout the feeding trials, the amount of energy allocated to growth never fell below the maintenance requirements (Figure 6). The peak in the growth component of her energy budget occurred at approximately 50 percent of adult weight (2.5 weeks old). It steadily decreased until she had attained approximately 75 percent of her adult weight (3.5 weeks old). The subsequent increase observed in the growth energy component of the energy budget appears unrealistic, and again may be due to the cost of increased activity not accounted for by this model.

The relation between the energy ingested and the amount deposited in growth (feathers and body components) also should be considered. Typically, this is expressed as gross energy efficiency (growth energy divided by intake energy), or net energy efficiency (growth energy divided by metabolized energy)(Kleiber 1961). For all calculations of growth efficiency I used a correction factor of 0.75 to account for production efficiency of converting metabolized energy into feathers and body components (Ricklefs 1974).

The mean gross energy efficiency for Golden eagle chicks was 29.3 percent, decreasing from 40.8 percent at two weeks of age to 25.0 percent just prior to fledging. The Prairie falcon and Red-tailed hawk chicks had gross energy efficiencies of 30.2 and 39.0 percent, respectively. These chicks also exhibited a decreasing trend in efficiency throughout the feeding trials. Westerterp (1973) suggests that the efficiency of growth is strongly influenced by the type of food consumed. The greater observed gross energy efficiencies of the Prairie falcon and Red-tailed hawk chicks may reflect the tremendous fat content contained in their ground squirrel food. This would support Westerterp's interpretation.

Similar gross energy efficiencies have been reported for other non-passerines. Kahl (1962), Brisbin (1965) and Koelink (1972) reported that Wood storks (Mycteria americana), Herring gulls (Larus argentatus) and Pigeon guillemots(Cepphus columba) were 24 percent, 26 percent and 34 percent efficient, respectively.

Net growth efficiencies calculated for the Golden eagle chicks averaged 38.9 percent. The net growth efficiencies of the Prairie falcon and Red-tailed hawk chicks averaged 36.0 and 46.0 percent, respectively. Since growth efficiencies consistently decreased with increasing size, the lower efficiency observed in the Prairie falcon chick probably reflects the fact that over 80 percent of adult weight was achieved prior to the first feeding trial.

Few net growth efficiencies are available in the literature. Davidson et al (1968) and Westerterp (1973) have calculated that domestic fowl and Starlings (Sturnus vulgaris) exhibited n t growth efficiencies of 23 and 22 percent, respectively. These lower values reflect the less metabolizable seed and insect food presented to the birds. More data is needed on non-passerines, especially birds of prey, to judge the relative growth efficiencies exhibited by the chicks used in these feeding experiments.

The mean gross energy efficiency for Holstein cattle weighing was 39.2 percent, decreasing from 50.2 percent at the onset of age to 15.6 percent just prior to slaughter. The Hereford heifers and Aberdeen-Angus steers had gross energy efficiencies of 30.4 and 36.0 percent, respectively. Brody (1945) also established a diminishing trend in efficiency throughout the feeding period. Maynard et al (1979) suggests that the efficiency of growth is strongly influenced by the type of feed consumed. The greatest observed gross energy efficiencies of the Hereford heifers and Aberdeen-Angus steers may perhaps be attributed to a greater consumption of grain and the feed. This would support Maynard's recommendations.

The gross energy efficiencies have been examined for other non-ruminants. Paloheimo (1965), Beamish (1972) and Hassler (1970) reported that Brook trout (Salvelinus fontinalis), Rainbow trout (Salmo gairdneri) and Pinfish (Lagodon rhomboides) had efficiencies of about 24 percent, 35 percent and 29 percent with [illegible] respectively.

The growth efficiencies calculated for the Holstein cattle averaged 38.9 percent. The net growth efficiencies of the Hereford heifers and Red-angus beef steers are about 26.2 and 38.0 percent, respectively. These growth efficiencies considerably decreased with increasing size; the lowest efficiency observed of the Holstein cattle, which consumed the most feed (the 38 percent of total weight), was achieved prior to the final feeding trial.

The net growth efficiencies are not available in the literature. Kornbach et al (1962) and Hassler (1970) have estimated that Cottontail rabbits and Woodchuck (Marmota monax) exhibited a growth efficiency of 23 and 22 percent, respectively. These investigators reported the mean maintenance cost and lowest feed presented to the birds. This data is useful in comparisons, especially birds of prey, to judge the relative growth efficiencies exhibited by the steers used in these feeding experiments.

Partitioning Growth Energy Requirements

An attempt was made to partition the growth energy requirements for each feeding trial into the cost for producing body tissues and feathers (See Appendix VII). Two basic assumptions were used to calculate the cost of producing body tissue: (1) 75 percent production efficiency (Ricklefs 1974); and (2) that a linear relationship adequately predicts the energy density of body tissues as a function of age (Ricklefs 1974). The difference between the total growth energy available, and the calculated cost for producing the observed body growth was considered that energy available for feather development. This effort is only a first approximation, however, it suggests that the maximum energy demands for body and feather growth are staggered, with body growth peaking first. Intuitively, this result is satisfying, but more refined data is needed before any conclusions can be made.

Observed vs Predicted Metabolism

The subadult Prairie falcon was kept at a constant body weight during each feeding trial (Appendix IV). Therefore, existence metabolism, predicted by the modified Kendeigh equations (see Appendix VI) should equal the observed metabolized energy for each feeding trial. Paired t-tests were performed on the observed and predicted metabolic rates of feeding trials #2 through #7 (Table 4). Trials #1 and #8 were eliminated because of mechanical difficulties associated with collecting the excrement, which resulted in reduced ME values. No significant difference was found between the predicted and observed values for the six feeding trials considered ($t_{5df} = 1.495$, $p = 0.10$). Mean values were then calculated for existence metabolism for each feeding trial. These means reveal the inverse relationship which exists between existence metabolism and ambient temperature. As temperature decreases, the amount of energy required for thermoregulation increases.

Extrapolations to Free-living Metabolism

Wild nestlings normally exhibit minimal activity , and may expend energy at approximately existence levels. This would maximize the energy which would be available for growth, especially early in the brood-rearing period. As nestlings approach fledging weights, wing-flapping and other exercising may significantly elevate their metabolism. Simple multiples of existence metabolism have been used to estimate the energetic cost of free existence (Kahl 1964, Kale 1965), and might apply to energy budgeting of raptor chicks in the nest.

Other researchers have used time and activity budgets, with different caloric costs associated with each activity, to estimate the cost of free existence (West 1960, Schartz and Zimmerman 1971, Kendeigh 1972, Collopy 1975). An energy budget for free-living Prairie falcons could be calculated from a time budget and estimates of the energy costs of each behavior. These costs could be expressed as multiples of existence metabolic rate.

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Table 1. Data are presented on percent water content, percent fat (on a dry weight basis), and energy content of fat and fat-free carcass for each collection of prey used in the feeding trials. The feeding trials each prey collection was used in also is indicated.

PREY SPECIES	DATE COLLECTED	PERCENT WATER	PERCENT FAT	$kcal \cdot gm^{-1}$ FAT	$kcal \cdot gm^{-1}$ FAT-FREE	USED IN TRIAL #
Black-tailed jackrabbit (<u>Lepus</u> <u>californicus</u>)						
Collection #1	4/12/78	69.51	3.70	9.265	4.230	GE #1,2,3
Collection #2	5/7/78 5/12/78	70.93	2.48	9.265	4.293	GE #4,5
Collection #3	5/17/78	71.13	3.81	9.265	4.503	GE #6,7
Townsend ground squirrel (<u>Spermophilus</u> <u>townsendi</u>)						
Collection #1	2/22/78	68.15	15.10	9.217	4.509	PF_{sa} #1,2
Collection #2	3/10/78	67.84	15.91	9.217	4.264	PF_{sa} #3,4
Collection #3	4/19/78	65.02	27.60	9.318	4.103	PF_{sa} #5,6; PF #2; RTH #1,2,3
Collection #4	5/25/78	57.82	42.60	9.217	4.337	PF #1; RTH #4
Collection #5	5/31/78	58.86	39.10	9.183	4.174	PF_{sa} #6,7,8; PF #3,4

Table 2. The following data are stratified by each feeding trial for each study bird: total assimilation efficiency, fat assimilation efficiency, assimilation efficiency of fat-free food and prey source.

SPECIES/TRIAL #		ASSIMILATION EFFICIENCY TOTAL (%)	FAT (%)	FAT-FREE (%)	PREY SOURCE
Golden eagle (Bert)	-#1	78.19	96.19	76.67	BTJR - Collection #1
	-#2	77.86	97.95	76.16	BTJR - Collection #1
	-#3	75.97	98.32	74.09	BTJR - Collection #1
	-#4	74.18	89.82	73.32	BTJR - Collection #2
	-#5	70.13	82.99	69.43	BTJR - Collection #2
	-#6	71.28	91.36	69.64	BTJR - Collection #3
	-#7	75.90	94.40	74.39	BTJR - Collection #3
Golden eagle (Ernie)	-#1	76.16	96.78	74.42	BTJR - Collection #1
	-#2	78.56	96.67	77.04	BTJR - Collection #1
	-#3	74.13	96.44	72.26	BTJR - Collection #1
	-#4	71.35	86.53	70.51	BTJR - Collection #2
	-#5	73.19	92.82	72.12	BTJR - Collection #2
	-#6	72.54	95.81	70.65	BTJR - Collection #3
	-#7	71.65	95.65	69.69	BTJR - Collection #3
Prairie falcon subadult (Homer)	-#1	77.54	95.74	70.92	TGS - Collection #1
	-#2	76.77	99.54	68.49	TGS - Collection #1
	-#3	77.57	99.52	68.59	TGS - Collection #2
	-#4	78.80	99.43	70.36	TGS - Collection #2
	-#5	82.97	99.80	68.41	TGS - Collection #3
	-#6	84.22	99.71	68.02	TGS - Collections #3 + #5
	-#7	87.78	99.65	71.01	TGS - Collection #5
	-#8	86.59	99.53	68.32	TGS - Collection #5
Prairie falcon (Hazel)	-#1	86.70	99.06	67.21	TGS - Collection #4
	-#2	83.71	99.56	70.01	TGS - Collection #3
	-#3	81.61	99.29	56.63	TGS - Collection #5
	-#4	81.89	99.16	57.50	TGS - Collection #5
Red-tailed hawk (Red)	-#1	85.19	99.48	72.82	TGS - Collection #3
	-#2	85.39	99.17	73.46	TGS - Collection #3
	-#3	81.46	98.49	66.71	TGS - Collection #3
	-#4	86.71	99.28	66.86	TGS - Collection #4

Table 3. The following data are stratified by each feeding trial for each study bird: initial body weight, daily metabolized energy, existence metabolism, energy contributed to growth daily, and assimilation efficiency.

SPECIES/TRIAL #	INITIAL BODY WEIGHT (gm)	kcal • bird^{-1} • day^{-1} METABOLIZED ENERGY	EXISTENCE METABOLISM	GROWTH ENERGY	ASSIMILATION EFFICIENCY
Golden eagle (Bert) -#1	1012	464.747	141.776	322.971	78.19 %
-#2	1725	571.485	195.797	375.688	77.86 %
-#3	2375	582.717	234.777	347.940	75.97 %
-#4	3225	583.091	273.085	310.006	74.18 %
-#5	3700	473.319	301.533	171.786	70.13 %
-#6	3800	462.818	308.665	154.153	71.28 %
-#7	4000	574.282	314.984	259.298	75.90 %
Golden eagle (Ernie) -#1	321.9	245.926	72.293	173.633	76.16 %
-#2	800	388.202	124.158	264.044	78.56 %
-#3	1270	382.889	160.969	221.920	74.13 %
-#4	1785	389.133	187.586	201.547	71.35 %
-#5	2175	513.576	216.157	297.419	73.19 %
-#6	2950	468.482	263.673	204.809	72.54 %
-#7	3150	521.428	270.663	250.765	71.65 %
Prairie falcon sub-adult (Homer) -#1	547.9	64.246	104.275	0	77.54 %
-#2	546.2	87.564	98.146	0	76.77 %
-#3	517.1	85.720	95.026	0	77.57 %
-#4	527.0	85.707	98.169	0	78.80 %
-#5	509.2	85.084	91.490	0	82.97 %
-#6	491.3	87.112	83.659	0	84.22 %
-#7	491.2	86.746	80.280	0	87.78 %
-#8	481.5	67.558	79.395	0	86.59 %
Prairie falcon (Hazel) -#1	679.4	251.574	96.542	155.032	86.70 %
-#2	775	213.903	108.215	105.688	83.71 %
-#3	850	212.758	116.364	96.394	81.61 %
-#4	860	167.056	107.589	59.467	81.89 %
Red-tailed hawk (Red) -#1	477.9	301.923	84.324	217.599	85.19 %
-#2	718.9	251.350	98.656	152.694	85.39 %
-#3	855.8	249.206	120.077	129.129	81.46 %
-#4	999.8	317.576	126.398	191.178	86.71 %

Table 4. Comparison of observed and predicted rates of metabolized energy for a subadult Prairie falcon. Data for each feeding trial and the mean ambient temperature during that trial is presented.

SPECIES/TRIAL #		BODY WEIGHT (gm)	MEAN AMBIENT TEMPERATURE (°C)	METABOLIZED ENERGY[1] ME (KCAL/DAY)		
				OBSERVED	PREDICTED	MEAN
Prairie falcon						
subadult (Homer)	-#1	547.9	9.2	64.246[2]	104.275	(84.261)
	-#2	546.2	12.2	87.564	98.146	92.855
	-#3	517.1	12.2	85.720	95.026	90.373
	-#4	527.0	12.0	85.707	98.169	91.938
	-#5	509.2	13.6	85.084	91.490	88.287
	-#6	491.3	16.7	87.112	83.659	85.386
	-#7	491.2	18.4	86.746	80.280	83.513
	-#8	481.5	18.4	67.558[2]	79.395	(73.477)

[1] No significant difference was found between the observed and predicted rates of metabolized energy in feeding trials #2 through #7 ($t_{5\ df}=1.495$, $p = 0.10$). Based on this statistic I calculated means for ME.

[2] Feeding trials #1 and #8 were eliminated from analysis due to difficulties with experimental procedure which resulted in a reduced observed ME.

Figure 1. The assimilation efficiency of a subadult Prairie falcon is presented in relation to the percent fat in the diet. Each data point represents the percent fat in Townsend ground squirrels presented as food during that feeding trial. The data point at 0 percent fat is the mean assimilation efficiency, over all feeding trials, of fat-free ground squirrel material.

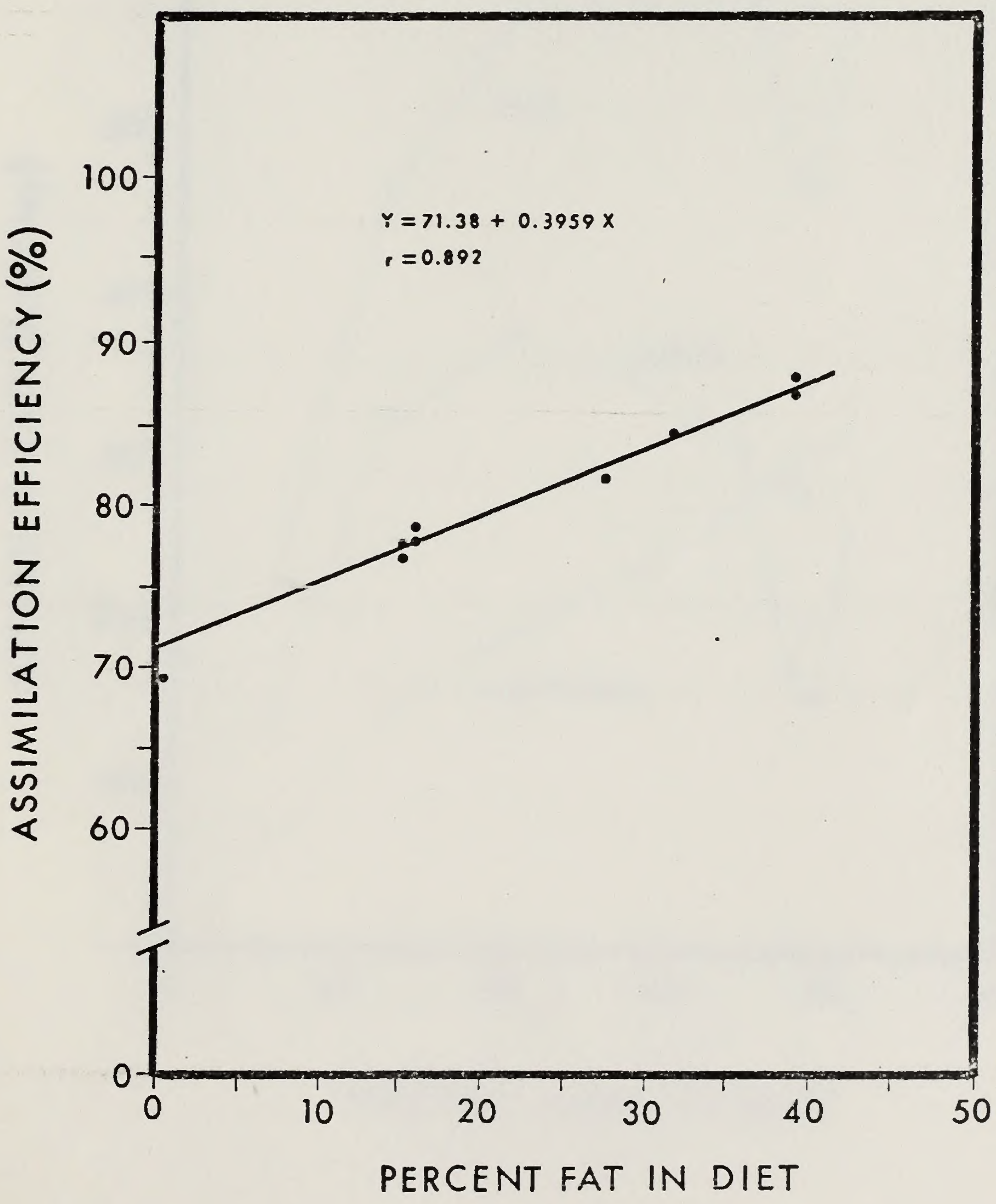


Figure 2. The metabolic rate of a Golden eagle chick (Bert) is presented in relation to percent adult weight for all feeding trials. The proportion of total metabolized energy allocated to maintenance and growth per feeding trial also is presented. (This chick was the older sibling)

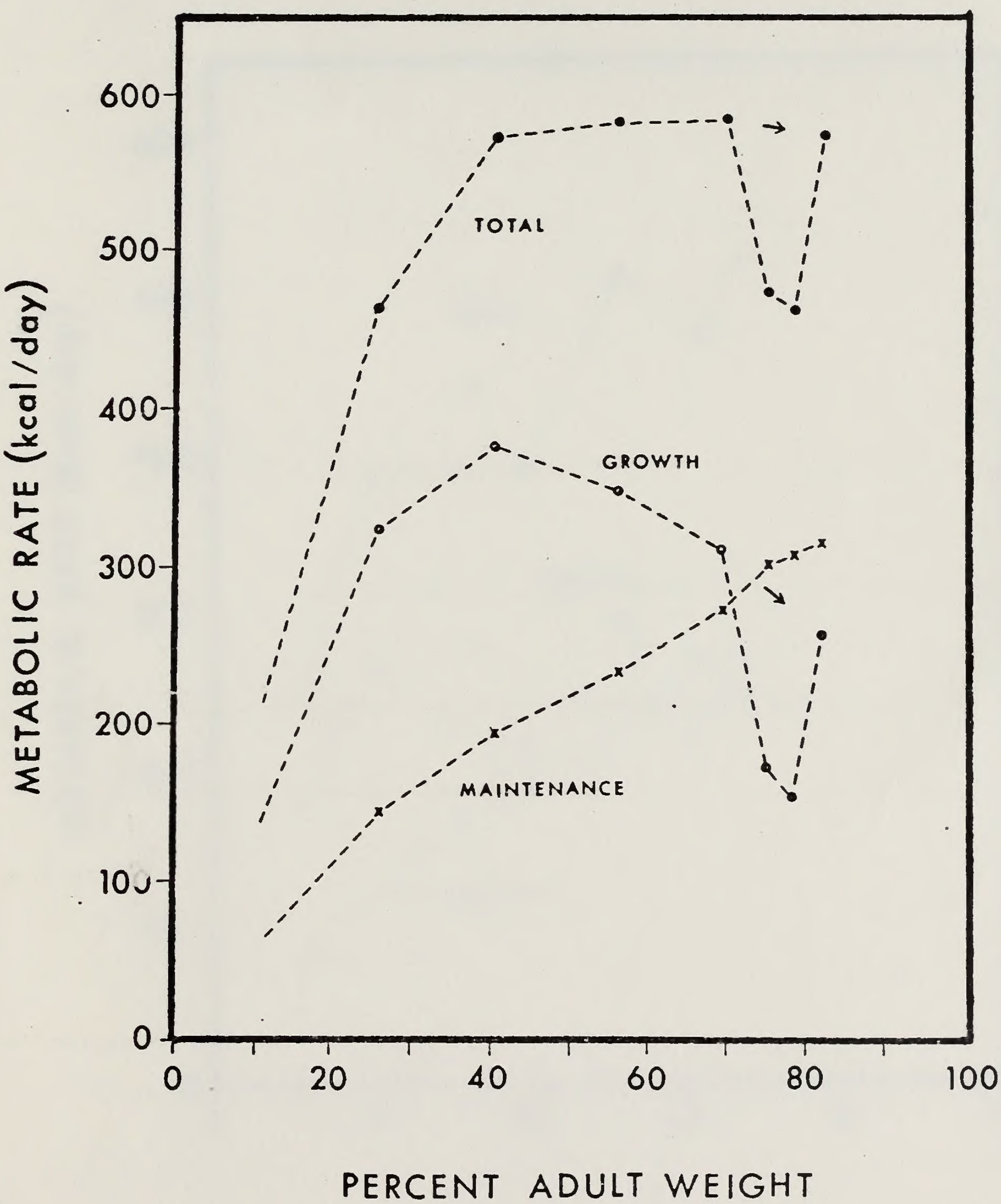


Figure 3. The metabolic rate of a Golden eagle chick (Ernie) is presented in relation to percent adult weight for all feeding trials. The proportion of total metabolized energy allocated to maintenance and growth per feeding trial also is presented. (This chick was the younger sibling)

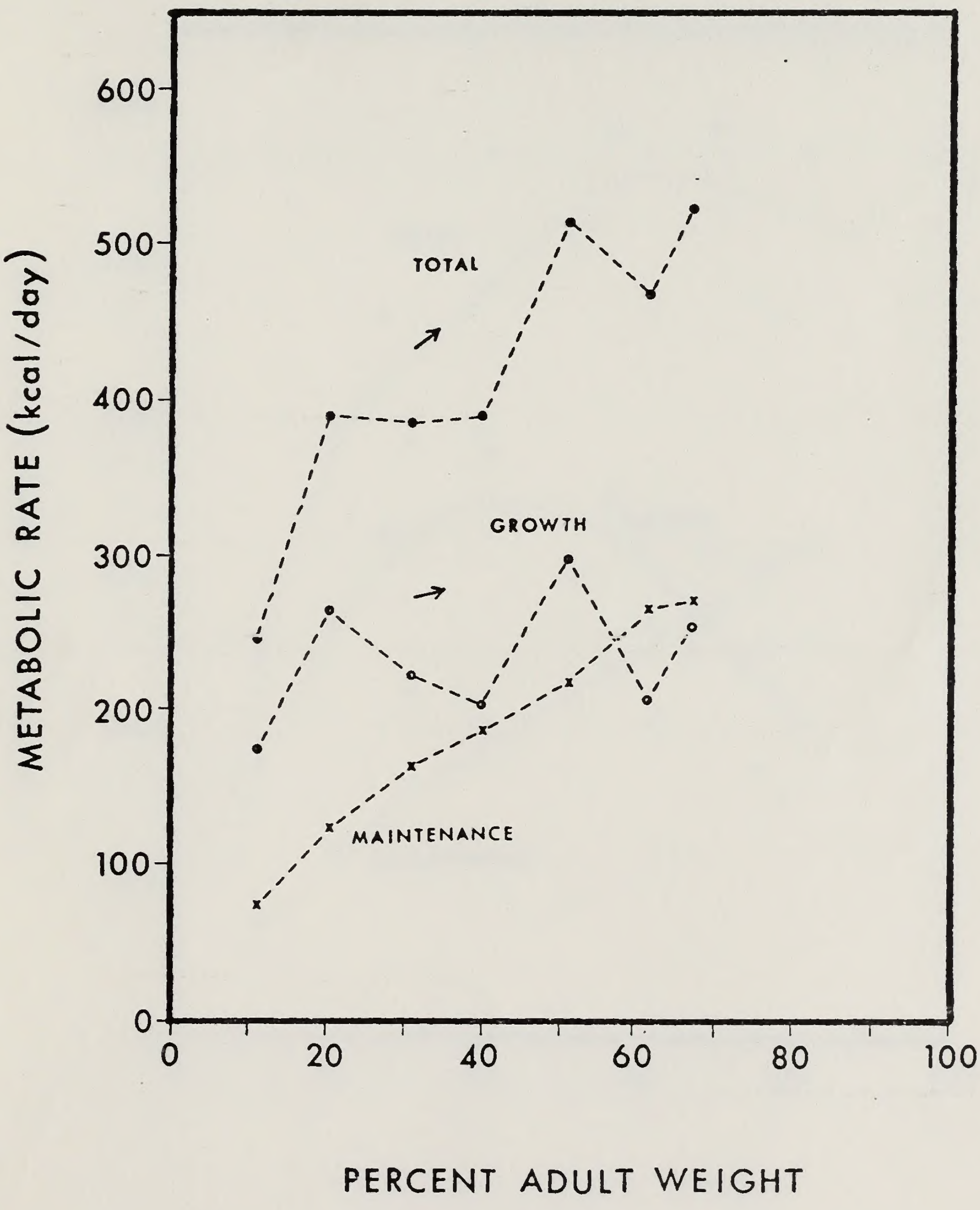


Figure 4. The metabolic rates of both Golden chicks are presented together in relation to percent adult weight for all feeding trials. The proportion of total metabolized energy allocated to maintenance and growth per feeding trial also is presented for each chick. (Lines were drawn in to simplify interpretation, but are only approximate)

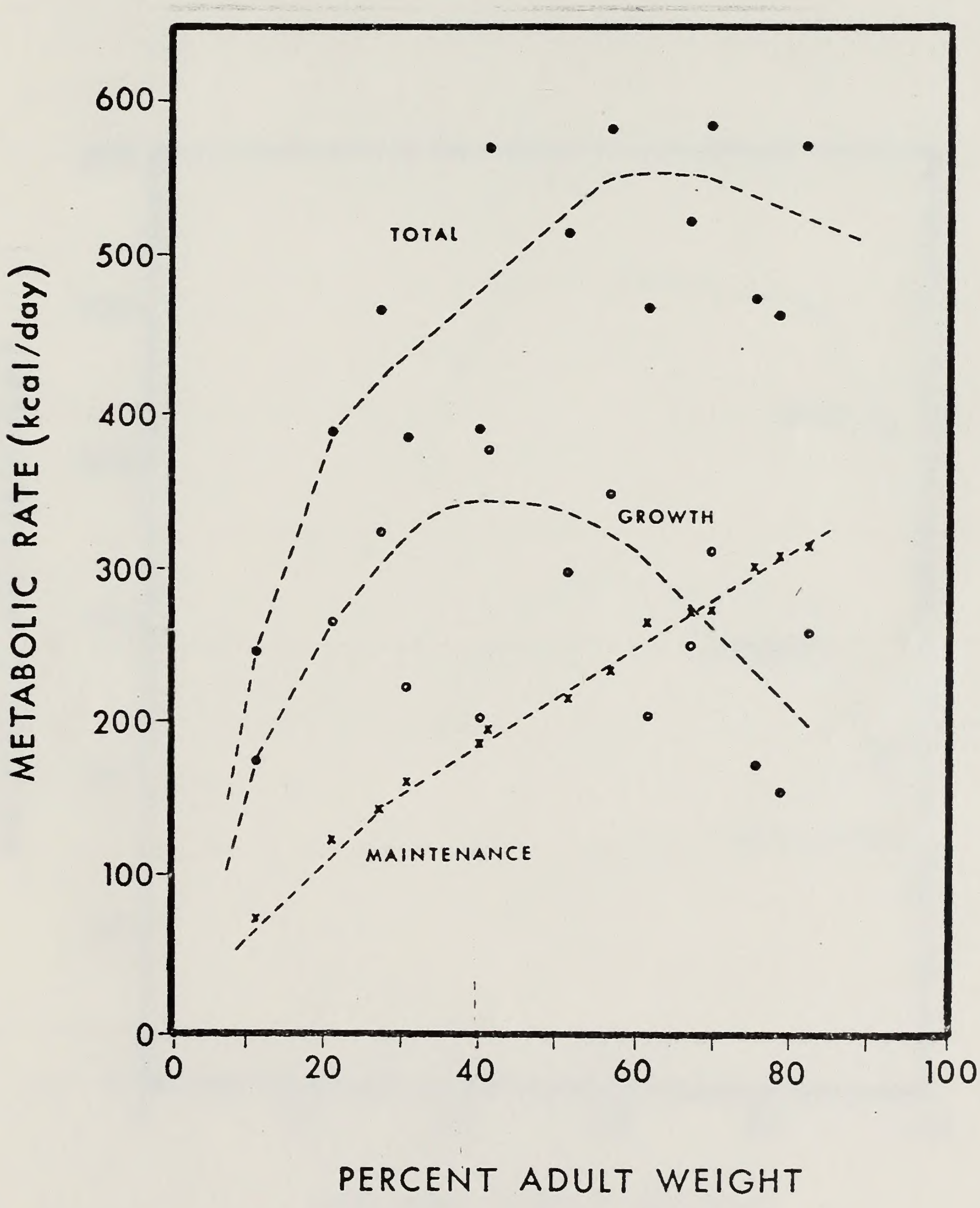


Figure 5. The metabolic rate of a Prairie falcon chick (Hazel) is presented in relation to percent adult weight for all feeding trials. The proportion of total metabolized energy allocated to maintenance and growth per feeding trial also is presented.

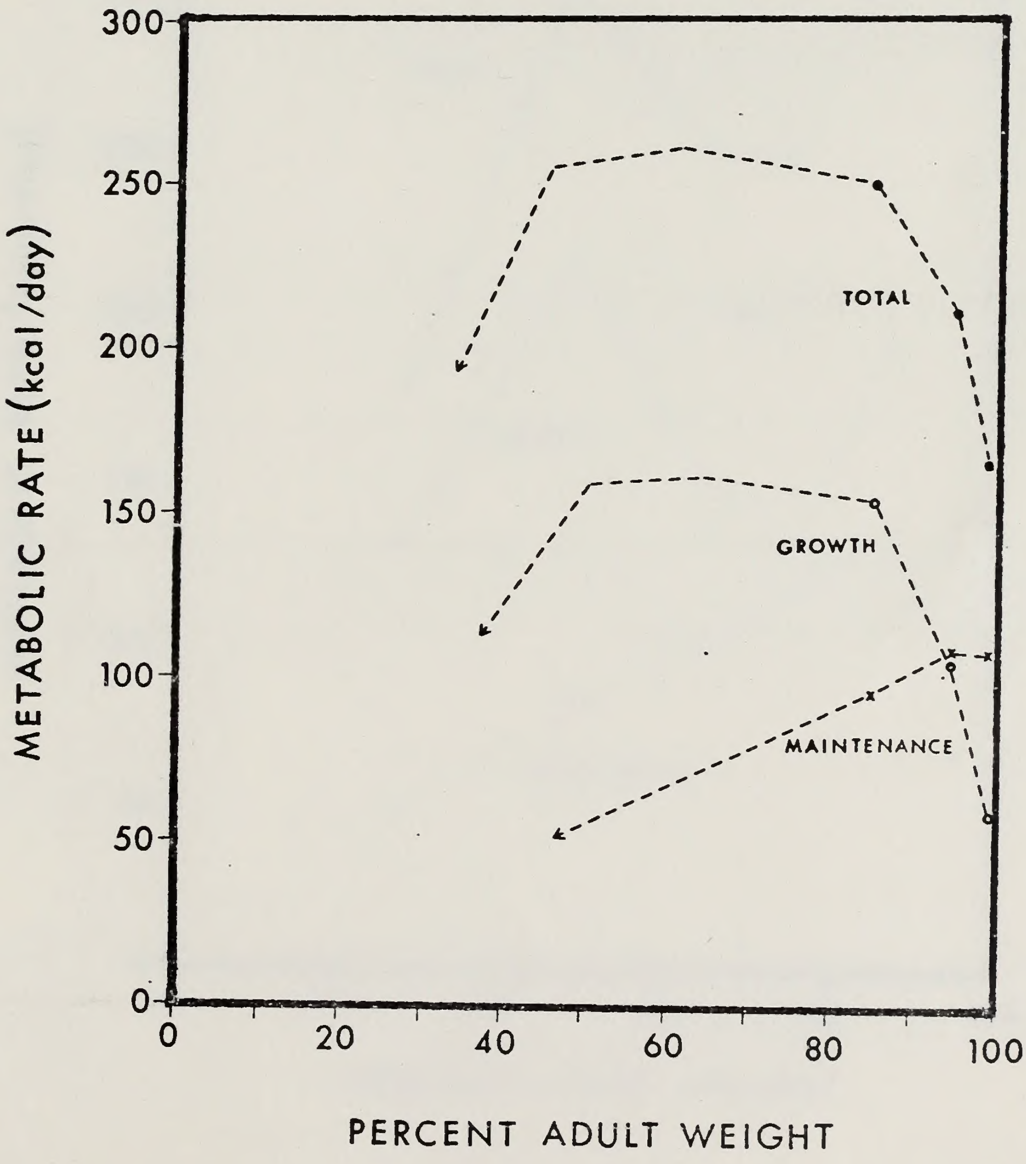
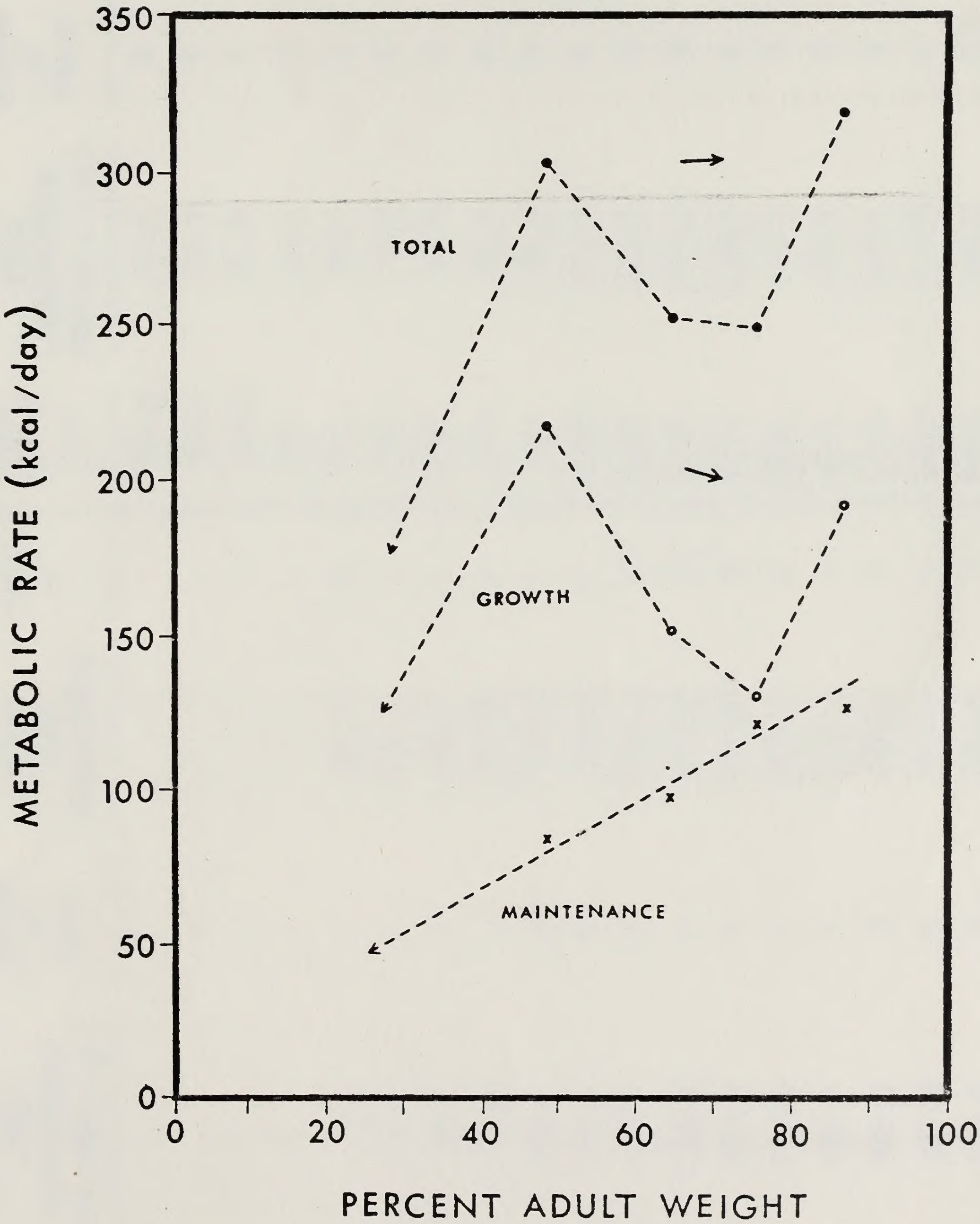


Figure 6. The metabolic rate of a Red-tailed hawk (Red) is presented in relation to percent adult weight for all feeding trials. The proportion of total metabolized energy allocated to maintenance and growth per feeding trial also is presented.



Appendix I. The age, body weight, average amount of food consumed per meal, number of meals per day, and total daily food consumption is presented for both Golden eagle chicks.

	Golden eagle (Bert)					Golden eagle (Ernie)				
AGE (day)	BODY WEIGHT (gm)	AVERAGE FOOD CONSUMPTION PER MEAL (gm)	NUMBER OF MEALS	TOTAL DAILY FOOD CONSUMPTION	TRIAL #	BODY WEIGHT (gm)	AVERAGE FOOD CONSUMPTION PER MEAL (gm)	NUMBER OF MEALS	TOTAL DAILY FOOD CONSUMPTION	TRIAL #
11	-	-	-	-	-	321.9	24.9	6	149.3	1
12	-	-	-	-	-	372.8	29.3	6	175.8	1
13	-	-	-	-	-	427.5	41.4	6	248.3	1
14	-	-	-	-	-	575	49.2	5	246.0	1
15	1012	71.9	5	359.6	1	625	60.1	5	300.4	1
16	1100	67.0	6	402.2	1	725	79.9	4	319.4	1
17	1225	64.8	6	388.5	1	800	69.8	5	349.0	2
18	1275	87.0	5	434.8	1	870	85.4	4	341.4	2
19	1412	100.0	5	499.8	1	925	85.9	4	343.6	2
20	1575	141.1	4	564.3	1	1025	100.2	4	400.6	2
21	1725	135.8	5	679.2	2	1150	105.6	4	423.6	2
22	1875	112.2	4	448.9	2	1270	166.7	3	500.0	3
23	1950	164.2	3	492.6	2	1300	138.0	2	276.0	3
24	2100	155.8	4	623.1	2	1350	102.6	3	307.7	3
25	2300	129.1	4	516.5	2	1400	169.1	2	338.2	3
26	2375	229.3	3	688.0	3	1500	209.1	2	418.2	3
27	2460	257.0	2	514.0	3	1625	234.9	2	469.8	3
28	2635	179.2	3	537.7	3	1785	165.0	2	330.0	4
29	2700	258.9	2	517.8	3	1850	234.4	2	468.7	4
30	2850	251.3	2	502.5	3	1975	243.8	2	487.6	4
31	2925	335.2	2	670.3	3	2050	275.0	2	549.9	4
32	3225	350.7	2	701.4	4	2175	151.2	2	302.3	4
33	3400	294.8	2	589.5	4	2150	200.9	2	401.7	4

Appendix I (continued).

AGE (day)	Golden eagle (Bert) BODY WEIGHT (gm)	AVERAGE FOOD CONSUMPTION PER MEAL (gm)	NUMBER OF MEALS	TOTAL DAILY FOOD CONSUMPTION	TRIAL #	Golden eagle (Ernie) BODY WEIGHT (gm)	AVERAGE FOOD CONSUMPTION PER MEAL (gm)	NUMBER OF MEALS	TOTAL DAILY FOOD CONSUMPTION	TRIAL #
34	3450	318.5	2	636.9	4	2175	260.4	2	520.7	5
35	3500	306.2	2	612.3	4	2275	256.2	2	512.3	5
36	3550	242.0	2	483.9	4	2360	336.8	2	673.5	5
37	3600	318.4	2	636.8	4	2600	275.6	2	551.1	5
38	3700	324.2	2	648.3	5	2700	277.9	2	555.8	5
39	3800	229.1	2	458.1	5	2800	271.7	2	543.3	5
40	3700	359.2	2	718.3	5	2875	274.5	2	548.9	5
41	3900	302.2	2	604.3	5	2950	520.6	1	520.6	6
42	3800	232.6	2	465.1	5	3050	375.5	1	375.5	6
43	3850	291.2	2	582.4	5	3050	429.3	1	429.3	6
44	3900	140.0	2	280.0	5	3050	500.9	1	500.9	6
45	3800	475.8	1	475.8	6	3050	454.7	1	454.7	6
46	3875	382.3	1	382.3	6	3075	544.3	1	544.3	6
47	3850	352.9	1	352.9	6	3150	516.3	1	516.3	7
48	3800	523.8	1	523.8	6	3220	506.1	1	506.1	7
49	3850	495.9	1	495.9	6	3200	555.0	1	555.0	7
50	3850	610.1	1	610.1	6	3250	448.1	1	448.1	7
51	4000	612.2	1	612.2	7	3250	550.5	1	550.5	7
52	4050	580.0	1	580.0	7	3400	664.0	1	664.0	7
53	4050	561.0	1	561.0	7	3500	-	-	-	-
54	4000	476.1	1	476.1	7	-	-	-	-	-
55	4000	592.4	1	592.4	7	-	-	-	-	-
56	4150	546.9	1	546.9	7	-	-	-	-	-
57	4150	-	-	-	-	-	-	-	-	-

Appendix II. The age, body weight, average amount of food consumed per meal, number of meals per day, and total daily food consumption is presented for a Prairie falcon chick.

AGE	BODY WEIGHT (gm)	AVERAGE FOOD CONSUMPTION PER MEAL (gm)	NUMBER OF MEALS	TOTAL DAILY FOOD CONSUMPTION	TRIAL #
21	679.4	40.9	3	122.6	1
22	731.4	42.2	3	126.5	1
23	745	36.5	3	109.4	1
24	775	39.1	2	78.2	1
25	775	63.9	2	127.7	2
26	785	69.8	2	139.5	2
27	810	61.5	2	122.9	2
28	825	63.1	2	126.1	2
29	850	43.3	2	86.6	3
30	825	64.9	2	129.7	3
31	875	62.8	2	125.5	3
32	860	36.9	2	73.7	3
33	860	45.1	2	90.2	4
34	860	48.2	2	96.3	4
35	875	44.6	2	89.2	4
36	885	25.6	2	51.1	4
37	850	-	-	-	-

Appendix III. The age, body weight, average amount of food consumed per meal, number of meals per day, and total daily food consumption is presented for a Red-tailed hawk chick.

AGE	BODY WEIGHT (gm)	AVERAGE FOOD CONSUMPTION PER MEAL (gm)	NUMBER OF MEALS	TOTAL DAILY FOOD CONSUMPTION	TRIAL #
15	477.9	41.2	4	164.6	1
16	542.4	44.3	4	177.2	1
17	598.0	43.1	4	172.4	1
18	650.6	43.1	4	205.6	1
19	718.9	45.0	4	175.9	2
20	776.8	41.8	4	167.0	2
21	817.6	44.3	3	132.9	2
22	840.6	47.0	3	141.0	2
23	855.8	43.8	3	131.3	3
24	873.7	51.2	3	153.7	3
25	907.9	65.2	3	195.5	3
26	960.7	55.7	3	167.1	3
27	988.1	47.1	3	141.4	3
28	999.8	55.2	3	165.7	4
29	1040.0	52.6	3	157.9	4
30	1092.3	61.3	2	122.6	4
31	1097.6	44.8	3	134.3	4
32	1128.0	39.0	3	117.1	4
33	1142.7	57.3	2	114.5	4
34	1133.8	-	-	-	-

Appendix IV. The date, trial number, body weight, number of meals per day, and total daily food consumption is presented for a subadult Prairie falcon. The mean ambient temperature also is indicated for each feeding trial.

DATE	TRIAL #	BODY WEIGHT (gm)	NUMBER OF MEALS	TOTAL DAILY FOOD CONSUMPTION	MEAN AMBIENT TEMPERATURE (°C.)
3/07/78	1	547.9	1	0	
3/08/78	1	512.4	1	38.9	
3/09/78	1	523.5	1	61.1	
3/10/78	1	548.9	2	56.0	9.2
3/11/78	1	540.0	2	72.3	
3/12/78	1	544.2	2	72.8	
3/13/78	1	546.2	-	-	
3/13/78	2	546.2	2	61.9	
3/14/78	2	547.2	2	65.0	
3/15/78	2	545.4	2	67.2	
3/16/78	2	541.2	2	80.9	
3/17/78	2	543.3	2	63.4	12.2
3/18/78	2	537.7	2	57.5	
3/19/78	2	539.1	2	63.0	
3/20/78	2	534.5	3	88.5	
3/21/78	2	543.3	-	-	
4/06/78	3	517.1	2	87.4	
4/07/78	3	525.0	2	70.6	
4/08/78	3	524.3	2	60.1	
4/09/78	3	519.3	2	85.8	
4/10/78	3	527.0	2	55.5	12.2
4/11/78	3	521.4	2	66.1	
4/12/78	3	521.3	2	53.9	
4/13/78	3	520.1	2	63.3	
4/14/78	3	521.0	-	-	
4/16/78	4	527.0	2	33.0	
4/17/78	4	514.6	2	71.2	
4/18/78	4	520.0	2	73.7	
4/19/78	4	523.2	2	55.9	12.0
4/20/78	4	519.7	2	85.2	
4/21/78	4	519.4	3	77.1	

Appendix IV (continued).

DATE	TRIAL #	BODY WEIGHT (gm)	NUMBER OF MEALS	TOTAL DAILY FOOD CONSUMPTION	MEAN AMBIENT TEMPERATURE (°C.)
5/03/78	5	509.2	2	50.5	
5/04/78	5	509.9	2	49.4	
5/05/78	5	507.9	2	34.1	
5/06/78	5	499.4	2	66.1	13.6
5/07/78	5	508.4	2	55.1	
5/08/78	5	510.5	2	59.4	
5/09/78	5	511.8	-	-	
6/10/78	6	491.3	2	30.9	
6/11/78	6	486.2	2	52.7	
6/12/78	6	491.1	2	49.4	
6/13/78	6	486.3	2	39.6	16.7
6/14/78	6	483.1	2	49.3	
6/15/78	6	480.3	2	51.1	
6/16/78	6	483.7	2	60.8	
6/17/78	6	491.2	-	-	
6/17/78	7	491.2	2	46.9	
6/18/78	7	488.4	2	36.1	
6/19/78	7	493.9	2	39.0	18.4
6/20/78	7	495.4	2	35.5	
6/21/78	7	494.8	-	-	
6/23/78	8	481.5	2	40.4	
6/24/78	8	486.8	2	23.2	18.4
6/25/78	8	481.1	2	37.9	
6/26/78	8	488.8	2	22.2	

Appendix V. Presented are the results from the bomb calorimetry and fat extraction analyses. The data are expressed on a dry weight basis.

SPECIES/TRIAL #		FAT-FREE ENERGY PELLETS (kcal/gm)	FAT-FREE ENERGY EXCREMENT (kcal/gm)	PERCENT FAT PELLETS	PERCENT FAT EXCREMENT
Golden eagle (Bert)	-#1	3.332	2.170	1.40	0.16
	-#2	3.893	2.239	0.92	0.10
	-#3	3.818	2.265	0.54	0.10
	-#4	4.096	2.200	4.63	0.07
	-#5	4.299	2.334	5.89	0.17
	-#6	4.501	2.489	6.10	0.22
	-#7	4.128	1.986	2.34	0.17
Golden eagle (Ernie)	-#1	3.196	2.221	1.64	0.10
	-#2	4.311	2.201	2.20	0.15
	-#3	4.209	2.419	2.00	0.12
	-#4	4.372	2.308	4.20	0.19
	-#5	4.010	2.335	2.46	0.16
	-#6	4.072	2.363	1.51	0.21
	-#7	3.879	2.360	1.40	0.20
Prairie falcon sub-adult (Homer)	-#1	4.290	2.250	0.40	0.14
	-#2	4.296	2.243	0.29	0.12
	-#3	4.357	2.219	0.29	0.15
	-#4	3.871	2.178	0.63	0.13
	-#5	3.587	2.061	0.28	0.11
	-#6	3.778	2.197	0.38	0.23
	-#7	4.199	2.306	0.16	0.55
	-#8	4.270	2.446	0.28	0.68
Prairie falcon (Hazel)	-#1	4.248	2.580	0.84	1.54
	-#2	3.934	2.356	0.67	0.31
	-#3	4.199	2.554	0.77	0.71
	-#4	5.139	2.708	0.96	1.00
Red-tailed hawk (Red)	-#1	4.241	1.965	2.43	0.01
	-#2	4.117	1.929	2.72	0.24

APPENDIX VI. Example worksheet used to calculate metabolized energy, existence metabolism, growth energy and assimilation efficiency.

GOLDEN EAGLE (Bert) Run # 1

Dates: 4/22/78 - 4/28/78

Age: 15 - 21 days

Length of Run: 144.0 hours

Body Weight (initial): 1012 gm

Body Weight (final): 1725 gm

Ambient Temperature:
Mean = 53.7 °F/ 12.1 °C
Maximum = 69 °F/ 20.6 °C
Minimum = 40 °F/ 4.4 °C

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Food Source: Black-tailed jackrabbit - Collection #1

% Water: 69.51 %

% Dry: 30.49 %

% Ash: _____ % (dry basis)

% Ash-free: _____ % (dry basis)

(Data on a dry-weight basis)

% Fat in carcass: 3.70 %, kcal/gm (fat) = 9.265

% Fat-free carcass: 96.30 %, kcal/gm (fat-free) = 4.230

kcal/gm (ash-free, fat-free) = 5.220

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Caloric equivalents: (fat-free)

	kcal/gm	kcal/gm (ash-free)	% ash-free (1-% ash)
Pellets =	3.332		
Excrement =	2.170		

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% fat	Data:	Biomass (total) -dry-	Biomass (fat)	Biomass (fat-free)	Biomass (fat-free, ash-free)	kcal (fat)	kcal (fat-free)	kcal (fat + ash-free)
	Food Consumed	807.74	29.89	777.86		276.897	3289.55	
1.40	Pellets Egested	49.52	0.693	48.827		6.423	162.69	
0.16	Excrement Egested	279.12	0.447	278.673		4.138	604.72	
	Metabolized (FI-R)	479.101	28.747	450.355		266.336	2522.14	

Total Metabolized Energy: (fat + fat-free)
Kcal : 2788.48 kcal
Kcal : _____ kcal (ash-free)

Digestion-Assimilation Efficiencies, based on:
Biomass consumed (dry weight) : 59.31 %
Kcal consumed : 78.19 %
Kcal consumed (ash-free) : _____ %

Appendix VII. The following data are stratified by each feeding trial for each study bird: percent of adult weight achieved by the end of the feeding trial, growth rate (g/day increase), total growth energy available, energy required to produce the observed increase in body weight and energy available for feather growth.

SPECIES/TRIAL #		% ADULT WEIGHT (final)[1]	GROWTH RATE (g/day)	$kcal \cdot bird^{-1} \cdot day^{-1}$ TOTAL GROWTH ENERGY AVAILABLE	ENERGY REQUIRED FOR OBSERVED GROWTH RATE[2]	ENERGY REMAINING FOR FEATHER GROWTH[3]
Golden eagle (Bert)	-#1	34.8	118.83	322.971	183.320	139.651
	-#2	47.9	128.40	375.688	210.904	164.784
	-#3	65.0	141.18	347.940	264.303	83.637
	-#4	74.6	79.44	310.006	170.583	139.423
	-#5	76.6	13.99	171.786	30.475	141.312
	-#6	80.6	33.80	154.153	75.666	78.487
	-#7	83.6	24.91	259.298	56.904	202.394
Golden eagle (Ernie)	-#1	16.1	79.68	173.633	100.246	73.387
	-#2	25.6	92.84	264.044	130.203	133.841
	-#3	36.0	85.54	221.920	133.483	88.437
	-#4	43.8	65.23	201.547	109.521	92.026
	-#5	59.4	108.46	297.419	207.823	89.596
	-#6	63.5	33.80	204.809	66.880	137.929
	-#7	70.5	58.13	250.765	121.200	129.565
Prairie falcon (Hazel)	-#1	90.4	23.47	155.032	56.038	98.994
	-#2	99.2	19.15	105.688	48.278	57.410
	-#3	100.4	2.45	96.394	6.316	90.078
	-#4	99.2	2.47	59.467	0	59.467
Red-tailed hawk (Red)	-#1	58.7	61.21	217.599	116.633	100.966
	-#2	69.9	33.70	152.694	69.952	82.742
	-#3	81.7	28.80	129.129	64.949	64.180
	-#4	92.6	22.33	191.178	54.066	137.112

[1] Sources for adult body weights: GE (Kochert pers. comm.); PF (Beebe 1964); RTH (Brown and Amadon 1968).

[2] Assumptions: Energy density of birds, D = 0.76 + 1.14 ; W = % Adult weight (Ricklefs 1974) D = kcal/gm (wet weight)
Production efficiency = 75%. (Ricklefs 1974)

[3] Growth energy(feather) = Growth energy(total) - Growth energy(body tissue).

Observed Metabolized Energy (ME_{obs}): $ME_{obs} = \frac{\text{total ME}}{(\#\text{ hours})/24} = kcal \cdot bird^{-1} \cdot day^{-1}$

1. $ME_{obs} = kcal \cdot bird^{-1} \cdot day^{-1}$

$$= \frac{2788.48}{(144)/(24)} = 464.747\ kcal \cdot bird^{-1} \cdot day^{-1}$$

2. $ME_{obs} = kcal \cdot bird^{-1} \cdot day^{-1}$ (ash-free)

= __________ = __________

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Predicted Metabolized Energy ($ME_{pred} = EM_{Tamb}$; assuming no growth):

$EM_{Tamb} = a + b(Tamb)$; Tamb = C.

1. $$b = \frac{0.5404\ W^{0.7545} - 4.3372\ W^{0.5300}}{30} = \frac{100.030 - 169.808}{30}$$

(W=grams) = 1012 gm

$b = -2.32593$

2. $$a = 0.5404\ W^{0.7545} - b\ (T_{amb}^{30}) = 100.03 - (-2.32593)(30)$$

$a = 169.808$

3. $EM_{Tamb} = a + b(T_{amb}) = 169.808 + (-2.32593)(12.052)$

(for specific weight) $= 141.776\ kcal \cdot bird^{-1} \cdot day^{-1}$

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Energy Required for Growth (G)

1. $G = ME_{obs} - EM_{Tamb}$; if G = 0, then $ME_{obs} = EM_{Tamb}$ (constant weight)

if G > 0, then $kcal \cdot bird^{-1} \cdot day^{-1}$ difference is the allocation of energy for biosynthesis (ME_{obs} includes ash content)

$= 464.747 - 141.776$

$G = 322.971\ kcal \cdot bird^{-1} \cdot day^{-1}$